REPORT NO. PC-NAS-001

SEMI-ANNUAL PROGRESS REPORT

NSG-8002

(JANUARY 14 THROUGH JULY 15, 1974)

STUDY OF MATERIALS FOR SPACE PROCESSING

JULY 1974

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(NASA-CR-138867) STUDY OF MATERIALS FOR SPACE PROCESSING Semiannual Progress Report, 14 Jan. - 15 Jul. 1974 (Paine Coll., Augusta, Ga.) ~~15~~ 16 p HC $4.00 N74-29018
CSCL 11D G3/18 Unclas 43487

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NAME OF THE INSTITUTION:	Paine College 1235 Fifteenth Street Augusta, Georgia 30901
TITLE OF THE GRANT:	Study of Materials For Space Processing.
TYPE OF REPORT AND PERIOD COVERED:	Semi-Annual Progress Report January 14, 1974 through July 15, 1974
NASA GRANT NUMBER	NSG-8002
PRINCIPAL INVESTIGATOR:	Dr. R. B. Lal Assistant Professor in Physics Division of Natural Science and Mathematics
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REPORT NUMBER	PC-NAS-001

FOREWORD

The Semi-annual progress report on NASA Grant, NSG-8002, entitled "Study of Materials for Space Processing", covers the period from January 14, 1974 through July 15, 1974.

The major contribution to this program was given by the Principal Investigator. One undergraduate student of Paine College helped in collecting material from the library.

The work reported herein was performed under the technical direction of Mr. Tommy C. Bannister of Space Sciences Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama 35812. Helpful comments from Bannister are gratefully acknowledged.

Acknowledgements are due to the libraries of University of South Carolina, Columbia, South Carolina, Savannah River Plant, Aiken, South Carolina (AEC) and the Augusta College, Augusta, Georgia for providing the library facilities. Also acknowledgements are due to the National Science Foundation (NSF), COSIP-D Project for providing a part of the equipment needed for this project

ABSTRACT

The efforts towards the development of a handbook of materials feasible for growth in space in future NASA Missions has been continuing. Major emphasis has been placed in a literature survey towards identifying promising materials. Equipment for resistivity and hall effect set-up has been procured and will be installed soon.

TABLE OF CONTENTS

I. INTRODUCTION

The concept of manufacturing in space was first discussed in 1968 (ref. 1) at the Marshall Space Flight Center, Huntsville, Alabama. It was then emphasised that we must begin to exploit man's demonstrated ability to perform productive tasks in space, for a potential which will have a more direct and immediate impact on the industrial and economic strength of our society. Later in 1969 another conference on space processing and manufacturing (ref. 2) many scientists joined together to propose possible areas where growth in space in a near 0-gravity environment will be beneficial for mankind. The Skylab results (ref. 3) have strikingly verified the utility of space for research purposes. Their high proportions of interesting results indicates that space will be a fertile field for new discoveries in the area of material science.

The purpose of this program is divided into two parts:

a) To identify materials in different areas which are feasible for manufacturing processes in future missions of Natural Aeronautics and Space Administration (NASA). The criteria of selection of a material will be the available growth conditions on the future payloads, industrial and scientific importance and finally the economics of the growths. For this purpose a handbook of space materials will be developed after reviewing the available literature in open scientific journals and other NASA and other government supported research projects.

b) Experimental set-up will be made to characterize single crystals of semi-conductors and metals by electrical and magnetic measurements. Such measurements will elucidate the role of gravity on the growth of materials.

2.0 A STUDY COMPILATION OF DATA FOR POSSIBLE CANDIDATE MATERIALS FOR SPACE PROCESSING

To fully utilize the low gravity environment for materials processing it is useful to make a survey of possible condidate materials feasible for growth during the future space flights. A survey is being made of the available literature in open scientific journals. Articles published in the area of crystal growth and related fields are located by scanning the two major abstracting journals a) Physic Abstracts and b) Solid State Science Abstracts. Also important journals in the area of solid state physics, applied physics, material science and crystal growth are scanned for each month. Data published prior to the last five to six years has been obtained through different review articles and books. Also data on the flight experiments in the previous flights is being requested from the Principal Investigators of the respective flights experiments.

2.1 FORMAT OF THE HANDBOOK

Under the present study the following categories of materials are being considered.

a) Electro-optic materials - Lasers, Electro-optic switching and memory devices.

b) Materials for Semi-conducting devices - Light Emitting Diodes (LED), Microwave devices (IMPATT, varacter diodes, detectors, field effect transistors, mixers, etc.)

c) Acousto-Optic Materials -

d) Materials for magnetic memory devices - non-cubic garnets -

e) Ferroelectric materials -

f) Optical window materials -

g) Material for radiation detectors.

h) Materials for spectrographic standards.

i) Immiscible systems -

In each category different possible materials will be considered keeping in view the temperature requirements of the available furnace on the space laboratory. Design criteria of each device will be discussed and based on that recommendation will be given for the best two materials in a particular category to be considered for growth in space.

During this reporting period literature on different materials feasible for a particular device has been collected by consulting the science and solid state abstracts for the last three years. Also important journals are being scanned every month. A bibliography will be made for each category of material at the end of the program.

As an example the basis of selection of a material for microwave device (varacter diodes) is given below.

2.2 MICROWAVE DEVICE (Varacter Diodes)

Varacter diodes exhibit variations in junction capacitance with applied voltage and serve units of variable reactance for harmonic generation, tunning, switching and mixing.

REQUIREMENTS OF MATERIAL

The requirements for a material for fabrication of varacter diodes have been discussed in details by Irvin et. al. (ref. 4) and also recently by Shaw (ref. 5).

a) In general, the material should have a high carrier mobility to maintain minimum electrical resistance.

b) A low dielectric constant for minimum capacitance.

c) A large energy gap to minimize saturation currents and for potential higher temperature operation.

d) A high thermal conductivity.

Table I gives the properties of some possible materials for the fabrication of varacter diodes. An examination of Table I reveals that GaAs is superior to Si in all respects except thermal conductivity.

TABLE I (ref. 5)

MATERIAL	ENERGY GAP (ev)	MOBILITY (300 K) (M^2/V Sec.) ELECTRONS	HOLES	THERMAL CODUCTIVITY W/CmK	DIELECTRIC CONSTANT
Si	1. 1	1500	600	1.45	12
Ge	0.67	3900	1900	0.64	16
GaAs	1. 4	8500	400	0.46	12
InP	1. 3	4600	150	0.65	14

Ge possesses no clear advantages over Si and is more difficult to process.

Thus Si and GaAs are the dominant varacter material with latter being superior particularly for more demanding applications like, avlanche diodes, transferred electron devices, microwave field effect transistor.

Most of the microwave devices are fabricated within epitaxial layers. The growth of GaAs epitaxial layers in reduced gravity environment will produce better layers with improved characterstics. For GaAs, liquid phase epitaxy (LPE) is simpler as compared to vapor phase epitaxy (VPE) and takes shorter period of time. A detailed comparisen of the two techniques has been given by Shaw (ref. 5).

2.3 TABLE OF RESULTS

In discussion with Mr. Tommy C. Bannister of MSFC (Technical Officer of the Grant) a simple format for the final data has been evolved. Table II gives as an example the results as will be tabulated in the final report. Changes and improvements will be made during the course of the work in consultation with the technical officer.

TABLE II

APPLICATIONS	MATERIALS IN USE	TYPE OF GROWTH						COMMENTS	REF.
		CHEMICAL VAPOR PHASE EPITAXY	LPE	BRIDGMAN	CZOCHRALSKI	FLOAT ZONE	OTHER		
Electro-Optic Devices	Bismuth Titanate ($Bi_4Ti_3O_{12}$)	-	-	-	-	-	r. f sput-tring	Used for electro-optical switching optical display, memory applications	6
	Barium Strontiam Niobate $Ba_xSr_{1-x}Nb_2O_6$	-	-	-	X	-	-	Low voltage deflectors, big potential for space processing	7
	ZnO films	X	-	-	-	-	-		8
	GaAs			X	X	X			9
	Others								

TABLE II (Continued)

APPLICATIONS	MATERIALS IN USE	TYPE OF GROWTH CHEMICAL VAPOR PHASE EPITAXY	LPE	BRIDGMAN	CZOCHRALSKI	FLOAT ZONE	OTHER	COMMENTS	REF.
Semiconducting Devices	$In_{1-x}Ga_xP$	X						Light-emitting diode (LED) amd injection laser	10
	GaP	X						LED, Electro-optic modulator	11, 12
	$GaAs_{1-x}P_x$	X						Red LED Has a great potential for many devices. Can be improved in space growth	11, 13, 14,
	GaAs		X					GaAs is unique for many devices and has a potential for improvement in space processing	5, 11
	Si	X							9
	$Al_xGa_{1-x}As$	X	X					LED, LPE has more potential	

TABLE II (Continued)

APPLICATIONS	MATERIALS IN USE	TYPE OF GROWTH: CHEMICAL VAPOR PHASE EPITAXY	LPE	BRIDGMAN	CZOCHRALSKI	FLOAT ZONE	OTHER	COMMENTS	REF.
Acousto-Optic	$LiNbO_3$				X				15
	$PbMoO_4$ Lead Molybdate							Has higher figure of merit than $LiNbO_3$ and and has low loss for applications below 0-5 GH_z. Has a great potential for space processing	15
	ZnO films	X						films grown on saphire substrate	8
Magnetic Memory Device	Ortho-ferrites $R(Fe_2O_3)$ Where R is a rare earth						flux		16
	Hexagonal Ferrites								16
	Garnets $Tb_3Fe_5O_{12}$								16

The table II is in no way complete at thepresent time. It is only inserted in this report to just give an idea of the planned format.

3.0 SETTING-UP OF EQUIPMENT

The following equipment has already been purchased under this grant:

a) Model 610 Kiethley Electrometer
b) Hewlett packard model 6291A DC power supply
c) 1 ohm standard Leeds and Northrop Resistor
d) Single Zone Lindberg temperature controlled furnace. (1200^{0}C)
e) Other small supplies for resistivity set-up.

An 4" electromagnet with power supply is on order under the NSF-COSIP-D grant to the college. A hall effect gaussmeter is already purchased under the NSF Grant. These two pieces of equipment will be used for Hall effect work under this project.

Due to some unforeseen reason the delivery of the magnet has been delayed. It is expected anytime during this month. As soon as the magnet is received, the hall effect and resistivity set up will be arranged for characterization purpose. Progress will be communicated to the technical officer at MSFC.

4.0 TRIPS DURING THIS PERIOD

TRIP TO WASHINGTON D. C.

A trip was made to Washington D. C. on February 1, 1974 to attend the special session on "Studies in Space Processing" at the 10th annual meeting of the AIAA. Preliminary discussions were held regarding the project with the technical officer of the grant. Also discussions were held with Mr. Brian Montgomery of NASA, MSFC and

Dr. James H. Bredt of NASA Headquarters, Washington D. C.

TRIP TO HUNTSVILLE, ALABAMA

A trip was made to Huntsville, Alabama on April 30 through May 1, 1974 to attend the third Space Processing Symposium (skylab results) at the Marshall Space Flight Center. Contacts were made with different Principal Investigators of the Skylab experiments. An interesting session was attended on May 1, 1974 on "Beyond Skylab."

TRIP TO UNIVERSITY OF SOUTH CAROLINA, COLUMBIA, SOUTH CAROLINA

Trips are made periodically to the Science Library of the University of South Carolina, Columbia, South Carolina in connection with the work on this project.

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